



## Highly Stable PM Raman Fiber Laser at 1680 nm

**Svane, Ask Sebastian; Liu, Xiaomin ; Rottwitt, Karsten**

*Published in:*  
Proceedings of 2013 Conference on Lasers and Electro-Optics (CLEO)

*Publication date:*  
2013

[Link back to DTU Orbit](#)

*Citation (APA):*  
Svane, A. S., Liu, X., & Rottwitt, K. (2013). Highly Stable PM Raman Fiber Laser at 1680 nm. In *Proceedings of 2013 Conference on Lasers and Electro-Optics (CLEO)* (pp. CW1M.6). IEEE.

---

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

# Highly Stable PM Raman Fiber Laser at 1680 nm

Ask Sebastian Svane, Xiaomin Liu, and Karsten Rottwitt

DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Ørstedsgade 343, DK-2800 Kgs. Lyngby, Denmark.

assv@fotonik.dtu.dk

**Abstract:** We demonstrate thermal stabilization of a Raman fiber laser. At 1680 nm the laser emission exceeds 500 mW with a power variation below 0.5 %, both linewidth and wavelength variations are under 1 pm.

© 2013 Optical Society of America

**OCIS codes:** 140.3550 (Raman Lasers), 060.3510 (Fiber Lasers), 140.3425 (Laser Stabilization).

## 1. Introduction

Distributed Bragg reflector (DBR) Raman fiber lasers (RFL) operating outside the wavelength bands covered by typical rare-earth doped fiber lasers, have recently been demonstrated with pm linewidths (LW) [1, 2], along with distributed feedback RFL's enabling further LW reduction [3]. Narrow spectral LW and stable linear output polarization are required for applications, such as second harmonic generation, spectroscopy and wavelength (WL) conversion [4]. Narrow LW DBR-RFLs can suffer from output power variations of up to 40 % [2], when no means of stabilization is applied. In this paper we demonstrate a high degree of power and spectral stability for a narrow LW RFL, with sub pm variations of both the central WL and LW, along with output power variations below 0.5%.

We show the output power and LW stability of a monolithic DBR-RFL operating at 1680 nm with a 67 % slope efficiency and an output power exceeding 0.5 W. The investigated RFL, is pumped at 1564 nm and emits at the Raman gain peak at 1680 nm. We compare mechanical and thermal tuning and stabilization of the fiber Bragg gratings (FBG) defining such a cavity, and we show how the power and LW stability of the output is affected. To optimize the cavity with respect to stability we have implemented an active feedback temperature control of the FBGs based on proportional–integral–derivative (PID) control. In characterizing the RFL output stability, both the output power and spectral characteristics were monitored across a duration of several hours.

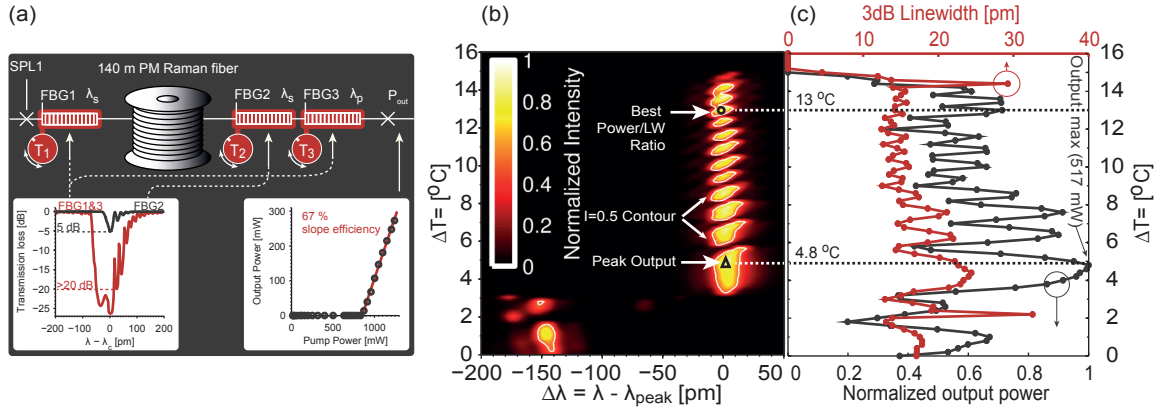


Fig. 1: (a) Experimental setup of the RFL along with the estimated FBG shape and output laser curve. (b) Normalized spectral output intensity as a function of the wavelength shift  $\Delta\lambda$  from the peak output WL and the temperature difference  $\Delta T$  between the FBGs. (c) Normalized output power and 3 dB LW as a function of  $\Delta T$ .

## 2. Experimental Results

The experimental setup is shown in Fig. 1(a), depicting a 140 m monolithic RFL cavity containing 3 FBGs. The Performance of the polarization maintaining (PM) RFL was discussed in [5]. The fiber is a PM Raman speciality fiber from *OFS Fitel Denmark*. FBG<sub>1</sub> and FBG<sub>2</sub> define the laser cavity, whereas FBG<sub>3</sub> acts as a pump reflector that provides increased pump efficiency through dual pass amplification. FBG<sub>1,3</sub> has an estimated reflectivity  $R > 99\%$  and FWHM of 135 pm. The output FBG<sub>2</sub> is estimated to have a reflectivity of 5 dB and FWHM of 28 pm. The output of the RFL depends on the alignment of FBG<sub>1</sub> and FBG<sub>2</sub>. The FBGs were realized by UV inscription with a 50 mm phasemask at *NKT Photonics*, for which the narrow LW gratings provides a high sensitivity to changes in temperature or mechanical perturbations. The WL tunability was 12 pm/°C for thermal tuning and 2.36 pm/mN for stretching.

In Fig. 1(b) the output spectrum of the RFL is mapped as a function of the temperature detuning  $\Delta T$  between the two signal FBGs. The triangle marks the peak output power value and the white contour lines enclose the area where the normalized intensity exceed 0.5. To the right in Fig. 1(c) the corresponding normalized total output power and LW is shown, where the output maximum is identified at  $\Delta T = 4.8^\circ\text{C}$ . The maximum output power is 517 mW, with a 24 pm LW. The best output power to LW ratio was found at  $\Delta T = 13^\circ\text{C}$ , resulting in an output power of 368.5 mW with a LW less than 14 pm, limited by the resolution of the used OSA. The output power was found to have a high degree of temperature sensitivity. A detuning of  $0.8^\circ\text{C}$  from the optimum value results in a 50% power reduction. The periodic structure of the spectrogram in Fig. 1(b) is a result of a non-uniform transmission spectrum of the FBG. The ripples in the grating transmission spectrum cause oscillations in the output when the relative grating alignment is adjusted.

Consistent with results in [2], it was found that without minor adjustments to the relative alignment of the two signal FBGs, the output of the RFL would be unstable both in terms of power variations, but also in terms of drifting WL of emission and changing LW. To increase the stability of the RFL, different means of alignment of the FBGs were investigated. Initially, the output FBG was adjusted using a micrometer-stage and a strain gauge providing a few mN of accuracy in the WL tuning of the FBG. The results are shown in Fig. 2(a), for which the measured std. deviation is indicated for the injected pump power, the output power, the change in LW and the shift in WL. An output power stability of 0.2% was obtained, whereas clear shift in WL along with LW changes were evident.

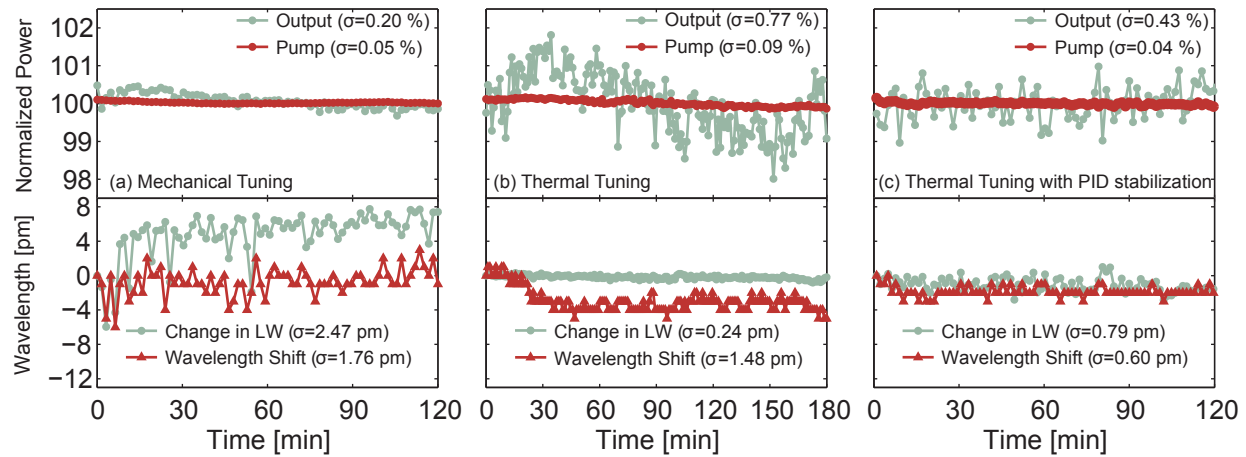


Fig. 2: Standard deviation in the RFL output power and spectrum for (a) mechanical tuning, (b) thermal tuning and (c) thermal tuning with PID stabilization.

Subsequently, thermal alignment of the FBGs was implemented by enclosing the FBGs in separate aluminium heatsinks connected to a peltier element. Tuning the FBG temperature, without feedback control, provided an increase in both LW and WL stability as depicted in Fig. 2(b). Temperature stabilization utilizing feedback from a thermocouple sensor enclosed in the heatsink along with PID control was realized, enabling accurate control and stabilization of the FBG. The results are shown in Fig. 2(c). A std. deviation in the measured FBG temperature of less than 20 mK was obtained. For an average output power of 680.5 mW and an average LW of 29 pm, a power stability of 0.43 % along with both a LW and WL stability below 1 pm was achieved.

### 3. Conclusions

Small alignment errors of the cavity FBGs impacts both output power, wavelength and linewidth, and a  $0.8^\circ\text{C}$  detuning between the gratings was found to reduce the output power by 50 %. The importance of accurate temperature alignment of the cavity gratings was demonstrated, with an output power exceeding 500 mW for a 24 pm linewidth and 368.5 mW for a linewidth less than 14 pm. As a consequence of our improved cavity design including active feedback control, a driftless output was obtained for 680 mW output power at 1680 nm with a std. deviation in both linewidth and central wavelength below 1 pm. Furthermore yielding output power variations below 0.5 %.

### References

1. A. Siekiera and R. Engelbrecht and R. Neumann and B. Schmauss, "Fiber Bragg gratings in polarization maintaining specialty fiber for Raman fiber lasers", *Physics Procedia* **5**, 671-677 (2010).
2. A. Siekiera, R. Engelbrecht, A. Nothofer, B. Schmauss, "Short 17-cm DBR Raman Fiber Laser With a Narrow Spectrum," *Photonics Technology Letters* **2**, vol.24, 107-109 (2012)
3. J. Shi, S. Alam, and M. Ibsen, "Raman DFB Fiber Laser with Truly Unidirectional Output," in *Bragg Gratings, Photosensitivity, and Poling in Glass Waveguides*, OSA, BW3E.6. (2012).
4. X. Liu, R. M. Osgood, Y. A. Vlasov & W. M. J. Green, "Mid-infrared optical parametric amplifier using silicon nanophotonic waveguides," *Nature Photon.* **4**, 557-560 (2010).
5. A. S. Svane and K. Rottwitz, PM Raman fiber laser at 1679 nm, Conference on Nonlinear Photonics (NP), Colorado Springs, JTU5A.28 (2012).